Rover Autonomy for Instrument Placement

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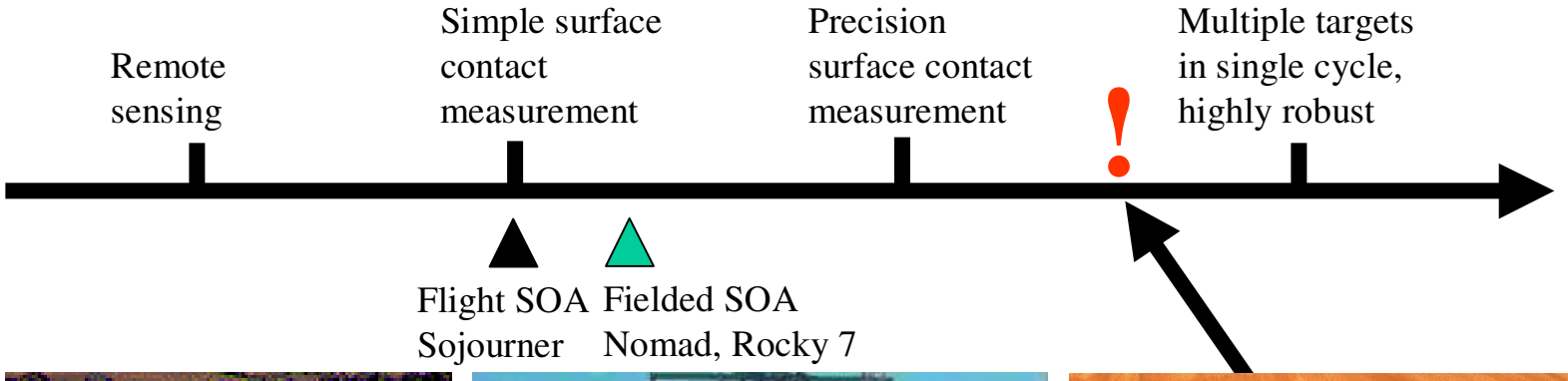
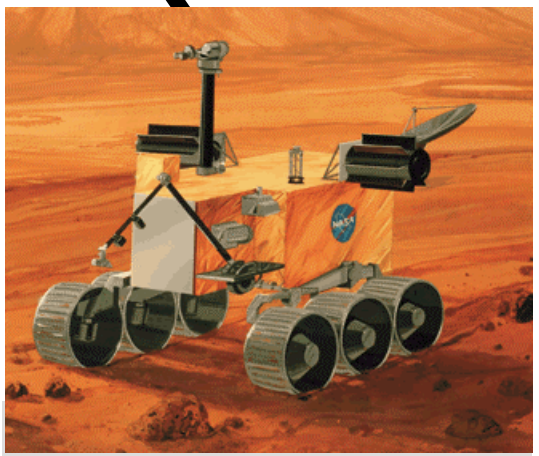
Goal: Single Cycle Target Approach and Instrument Placement



- >= 3 cycles per target, rigid command sequence
- Simple contact measurements

- Almost fully autonomous instrument placement with manipulator
- Simple environment
- Redesigned instrument

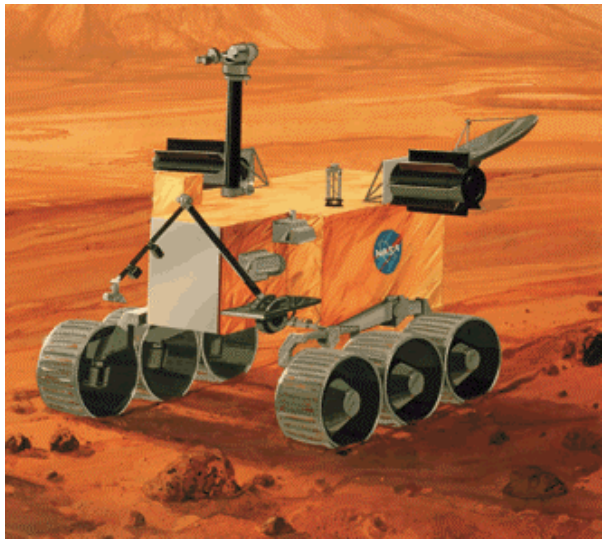


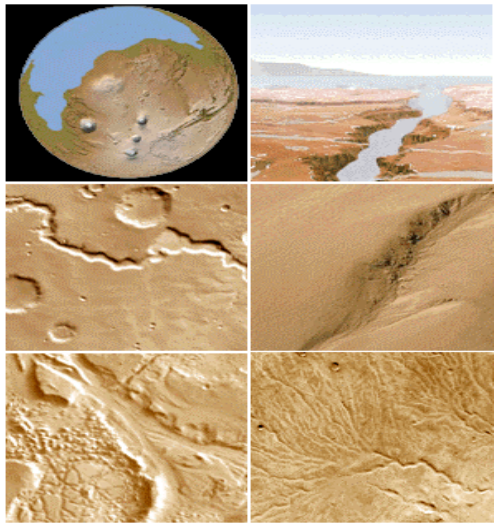
Mars '09 needs:

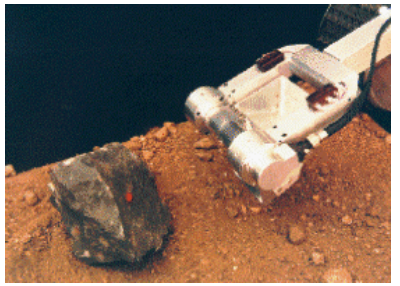
Precision surface contact measurement in single cycle.

Need for Target Approach and Instrument Placement

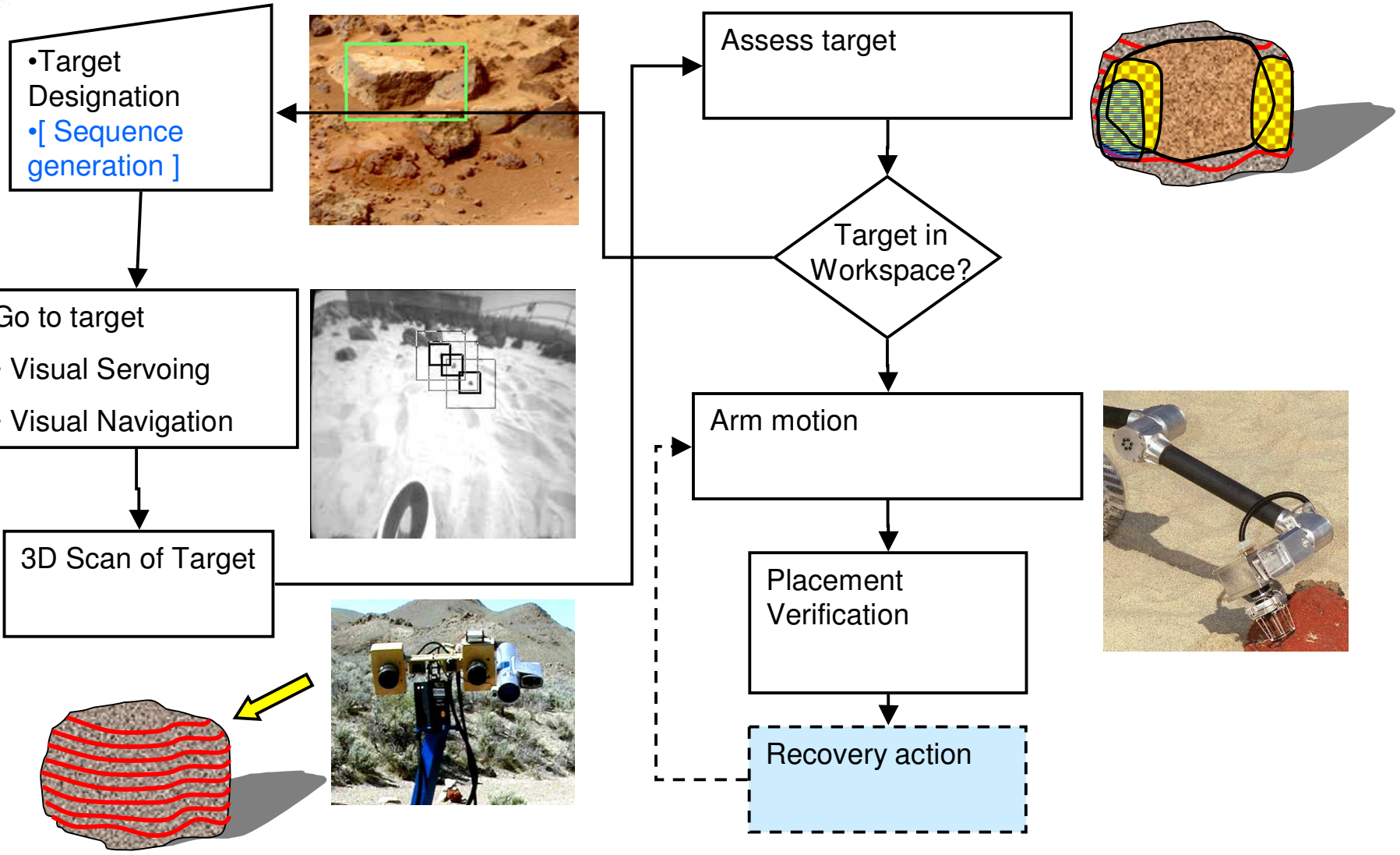
- Critical Mars '09 MSL need (was '07)
- Critical path to increasing science return through autonomy
  - Directly
  - Enables science autonomy
- Essential capability for any interesting science rover autonomy demonstration







Technical Approach



Target Designation using VIZ

VIZ virtual environment created from stereo images (NavCams, Science Cams or HazCams)

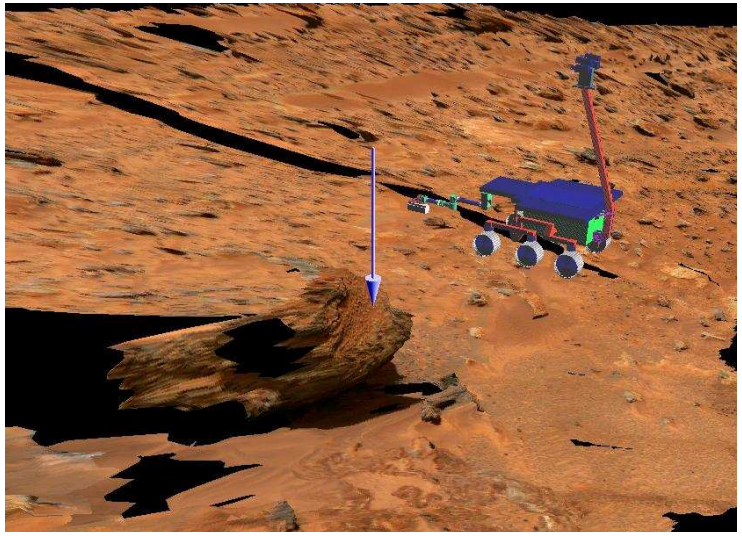
Operator selects rock target

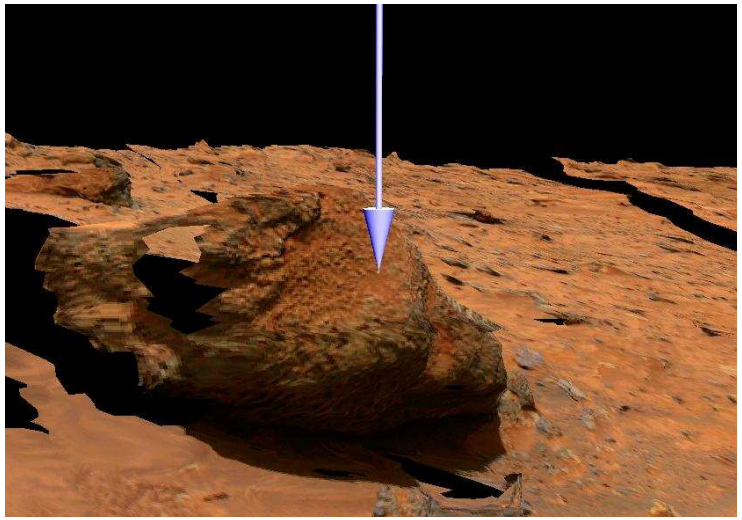
- **Point in 3D world**
- **Select region in corresponding image**

VIZ generates xyz coordinates or rock plus template image (to be used by target tracker in future).

[Information for automated sequence generation]

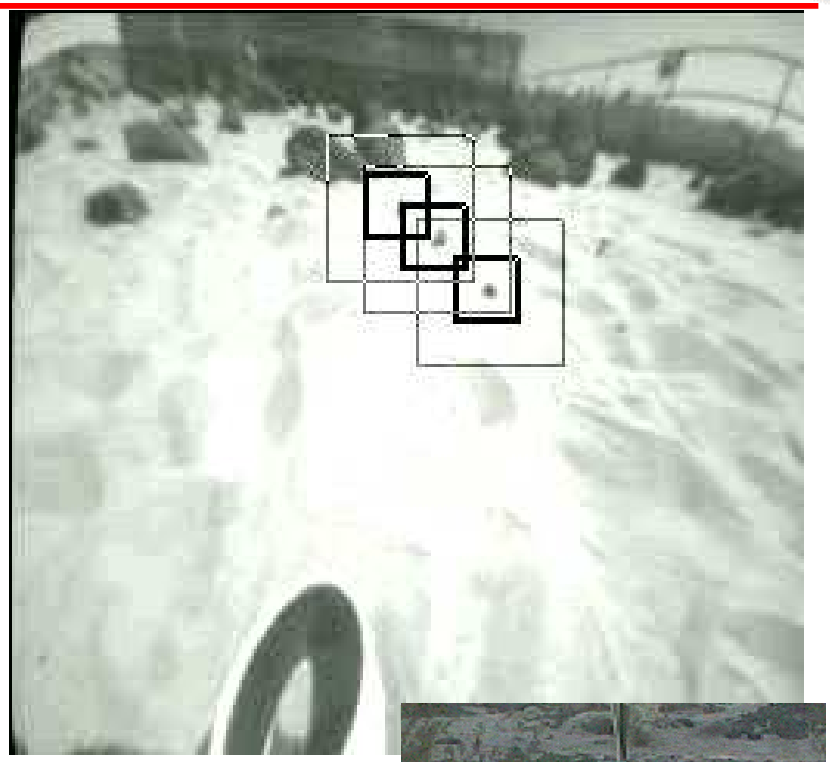
Can also visualize rover actions from telemetry



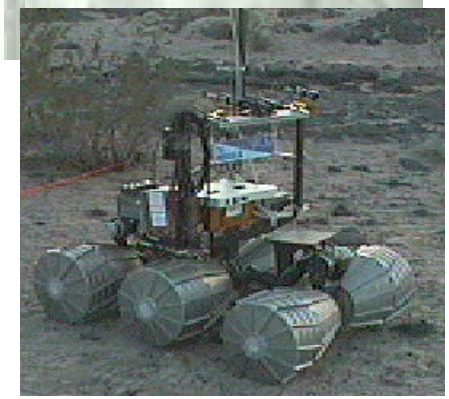


Visually Servoing to Target

- Visually track designated features, returning direction and distance to feature.
  - Control loop driving robot towards target until within some fixed distance.
- Will use Mars Technology Program deliverable:
  - Marsokhod (NASA Ames) 2D feature tracker
  - Rocky 7 (JPL) stereo based tracker
  - Combined hybrid approach
- Matt Deans (CMU 2002) will join this project



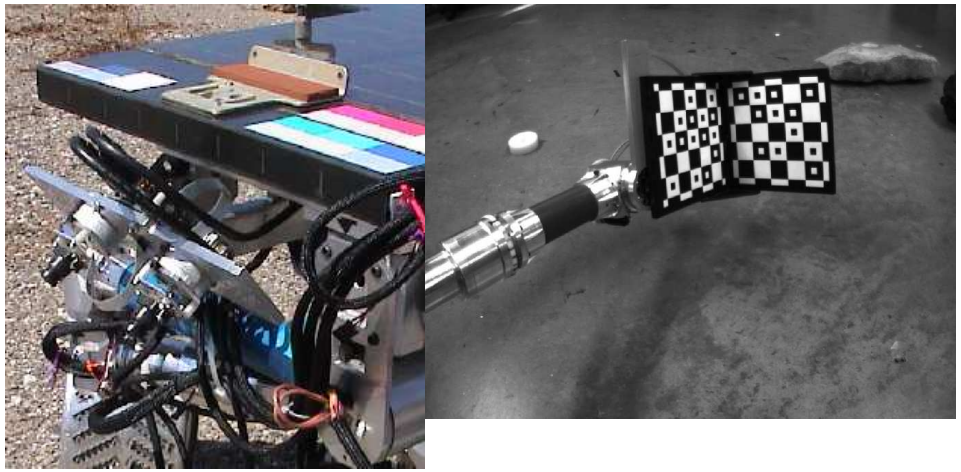
[Nesnas *et al*]

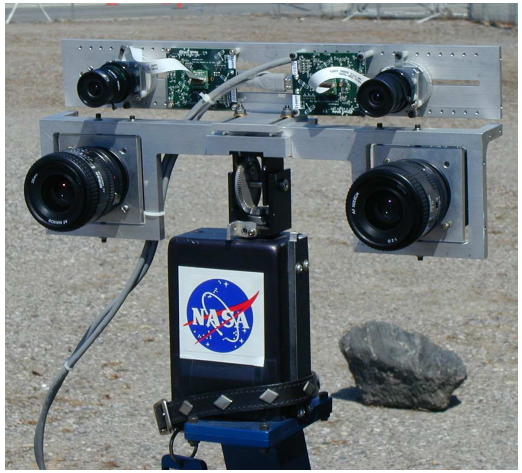


[Bualat *et al*]

3D Target Scanning with K9 Stereo Cameras

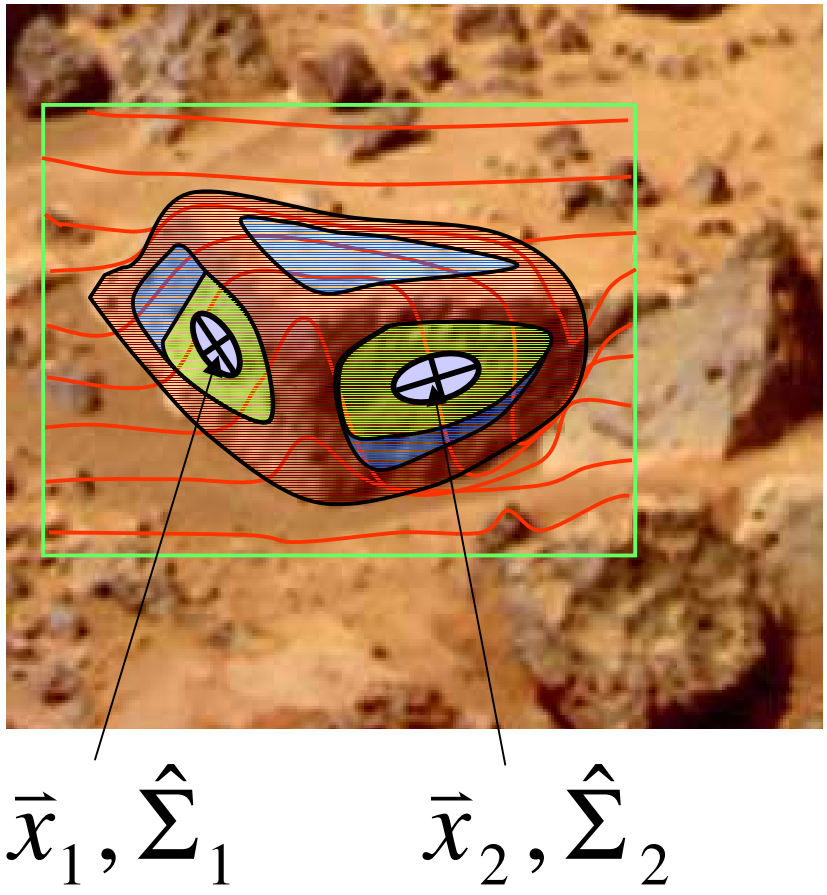
- K9 HazCams
  - Dragonfly hi-res (1000 X 800 pixel greyscale) firewire cameras.
  - Well calibrated wrt to rover coordinate frame
- Stereo correlation algorithm from Ames stereo pipeline.
- CLARAty image, camera and dotcloud classes
- Will eventually use NavCams and/or Science Camseras on K9 mast
  - New mounts
  - Will track targets with NavCams, potential hand-off problems
  - Harder to calibrate wrt to rover frame





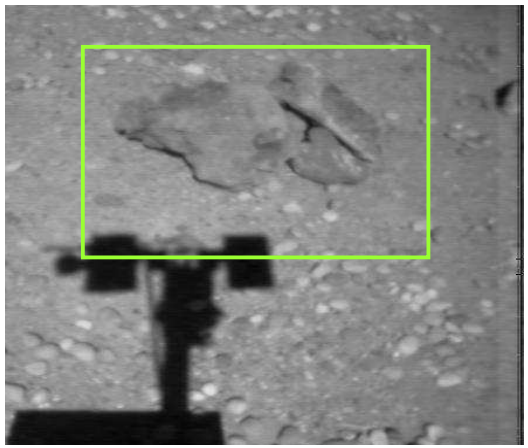
Target Assessment

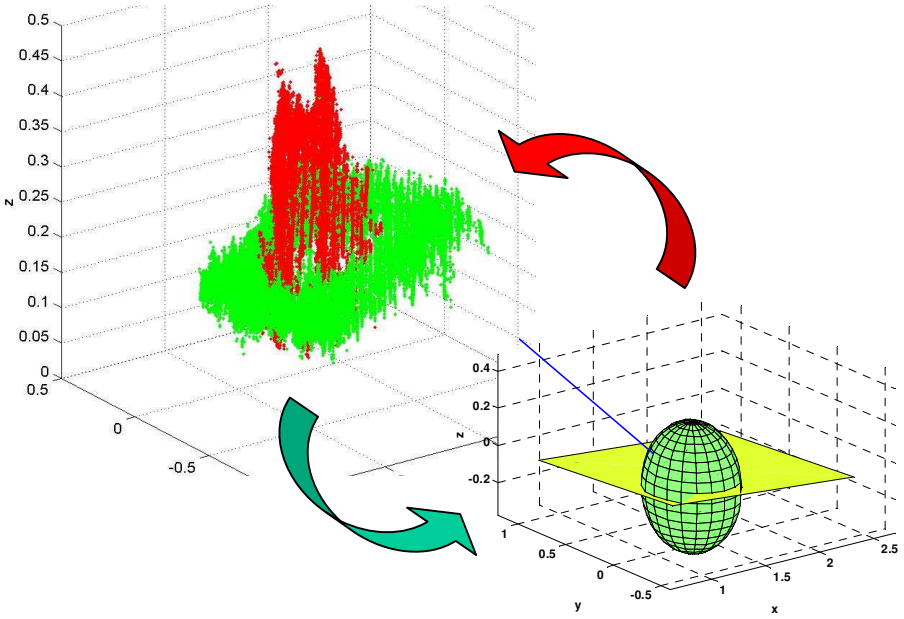
- [Target area scanned]
- Scientist desired area
  - Anywhere on rock ➔ segment rock from ground
- Patches consistent with instrument requirements
  - Flat disc within some tolerance
- Sub-patches in manipulator workspace
  - [effect of ground, other rocks]
- List of possible instrument poses with allowed error bounds and surface normals



Bayesian 3D Rock / Ground Segmentation

- Statistical mixture model of 3D dot clouds
  - Rock point distribution (spheres)
  - Ground point distribution (plane)
- Parameter estimation with hidden "nuisance" variables
  - K-means clustering
  - EM algorithm
- Future: geometrical and surface property (color, texture) constraints
- Publication: Liam Pedersen, "Science Target Assessment for Mars Rover Instrument Deployment", IROS 2002, October 2002

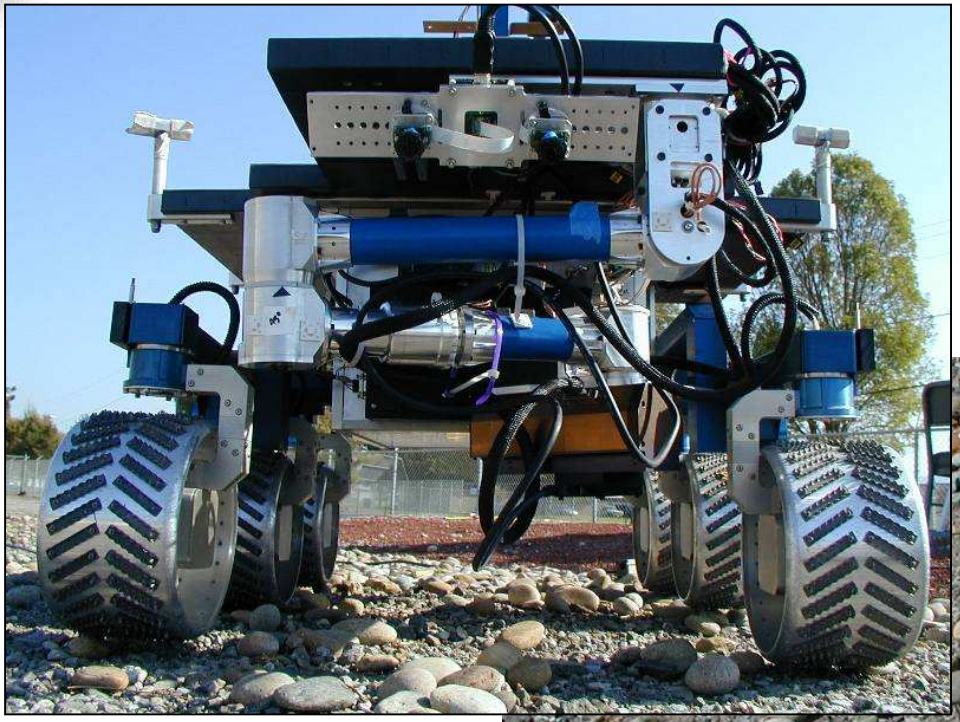


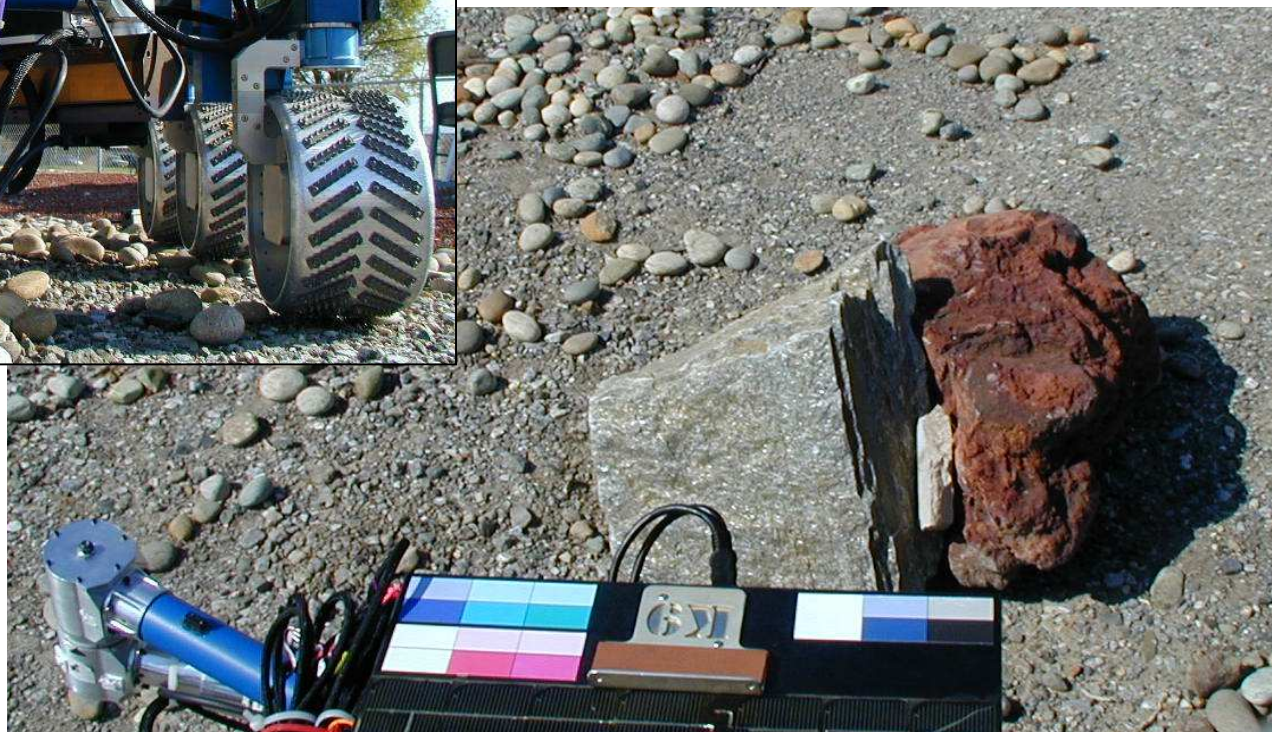


August 2002 Demo

- 2m approach
- Semi-complex outdoor scene
- Full instrument contact

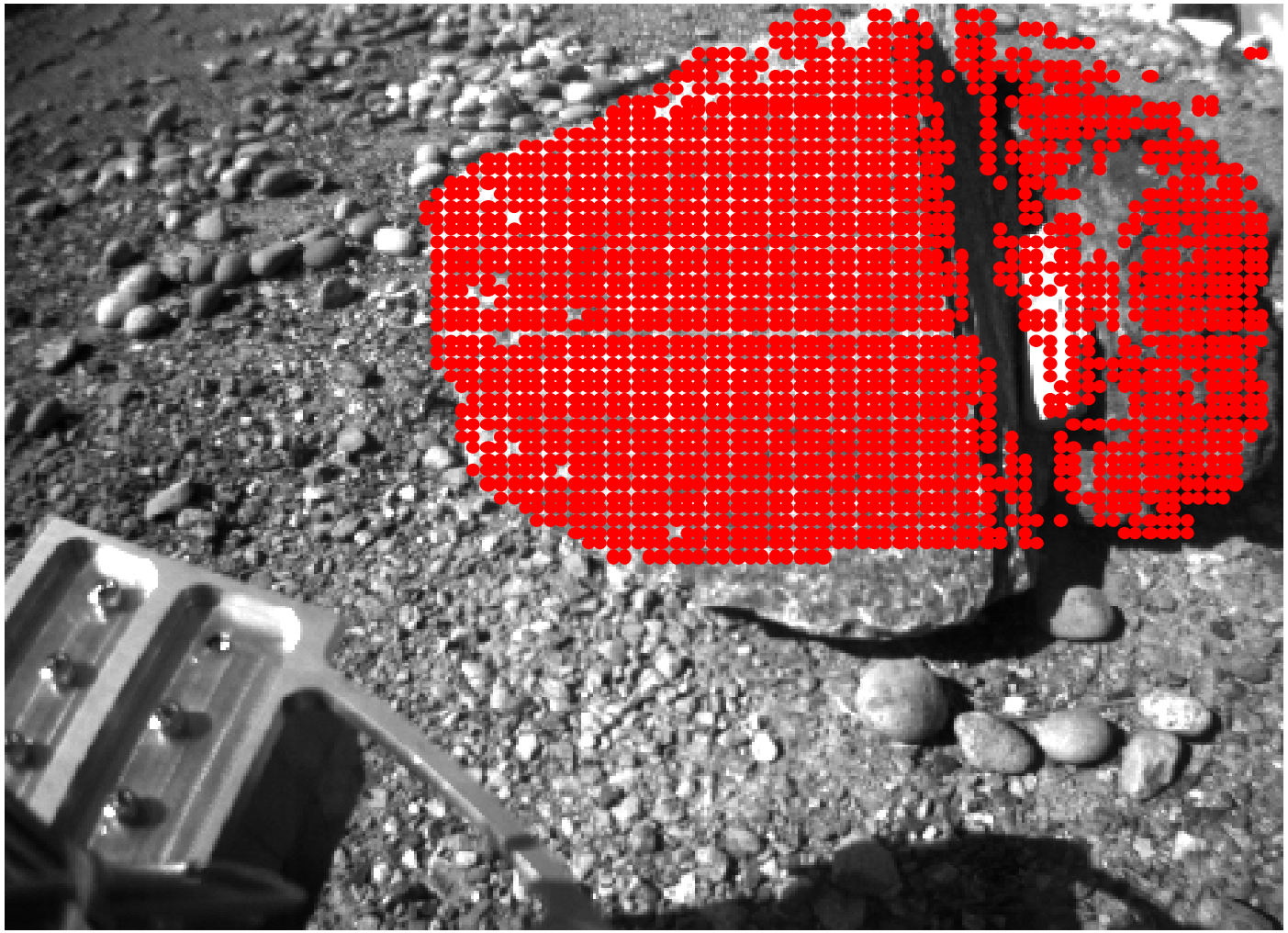
K9 Attacks Rocks
(August 2002 Outdoor Demo)





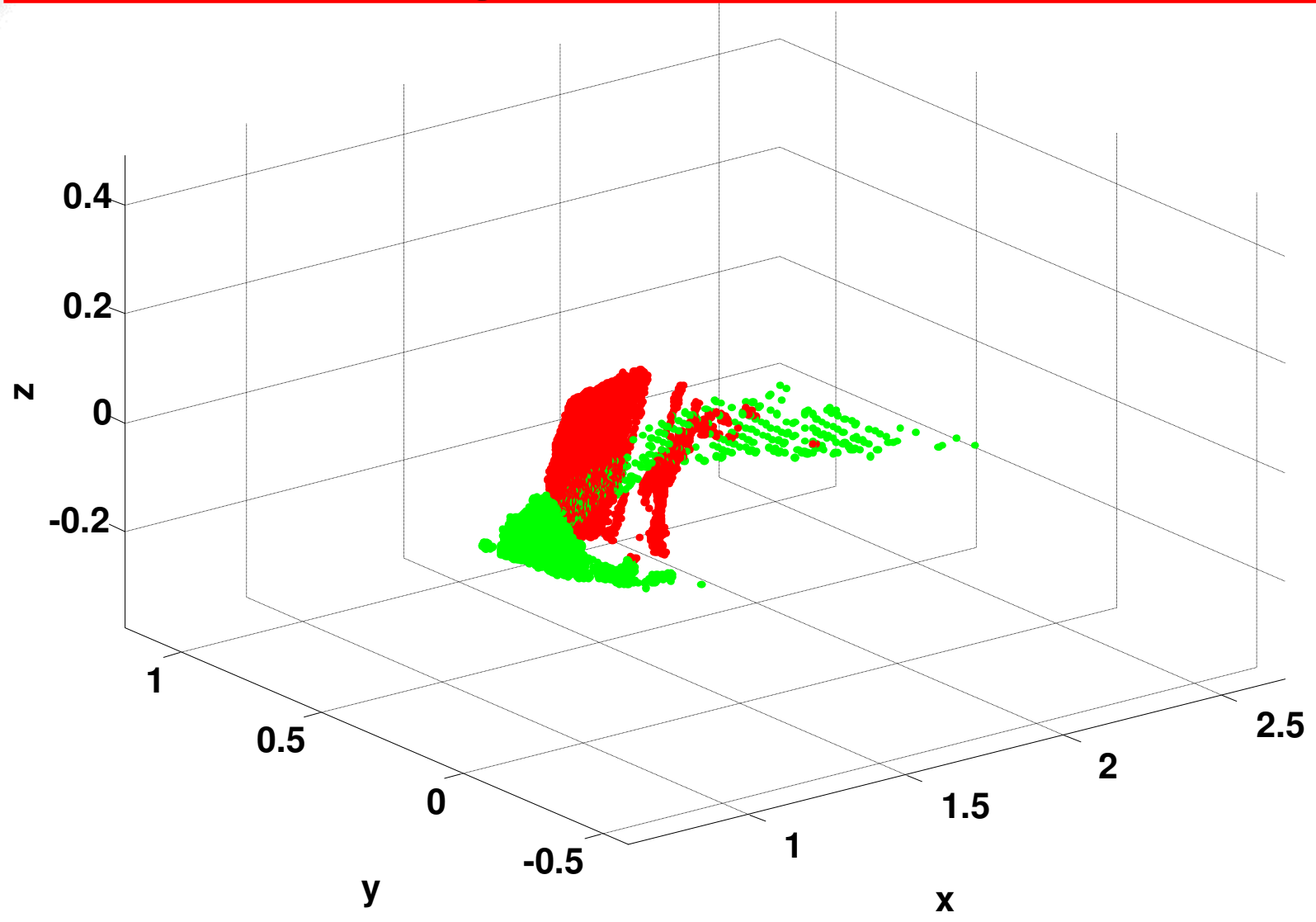
Rock & Ground Segmentation

(August 2002 Outdoor Demo)



Segmented 3D Point Cloud

(August 2002 Outdoor Demo)



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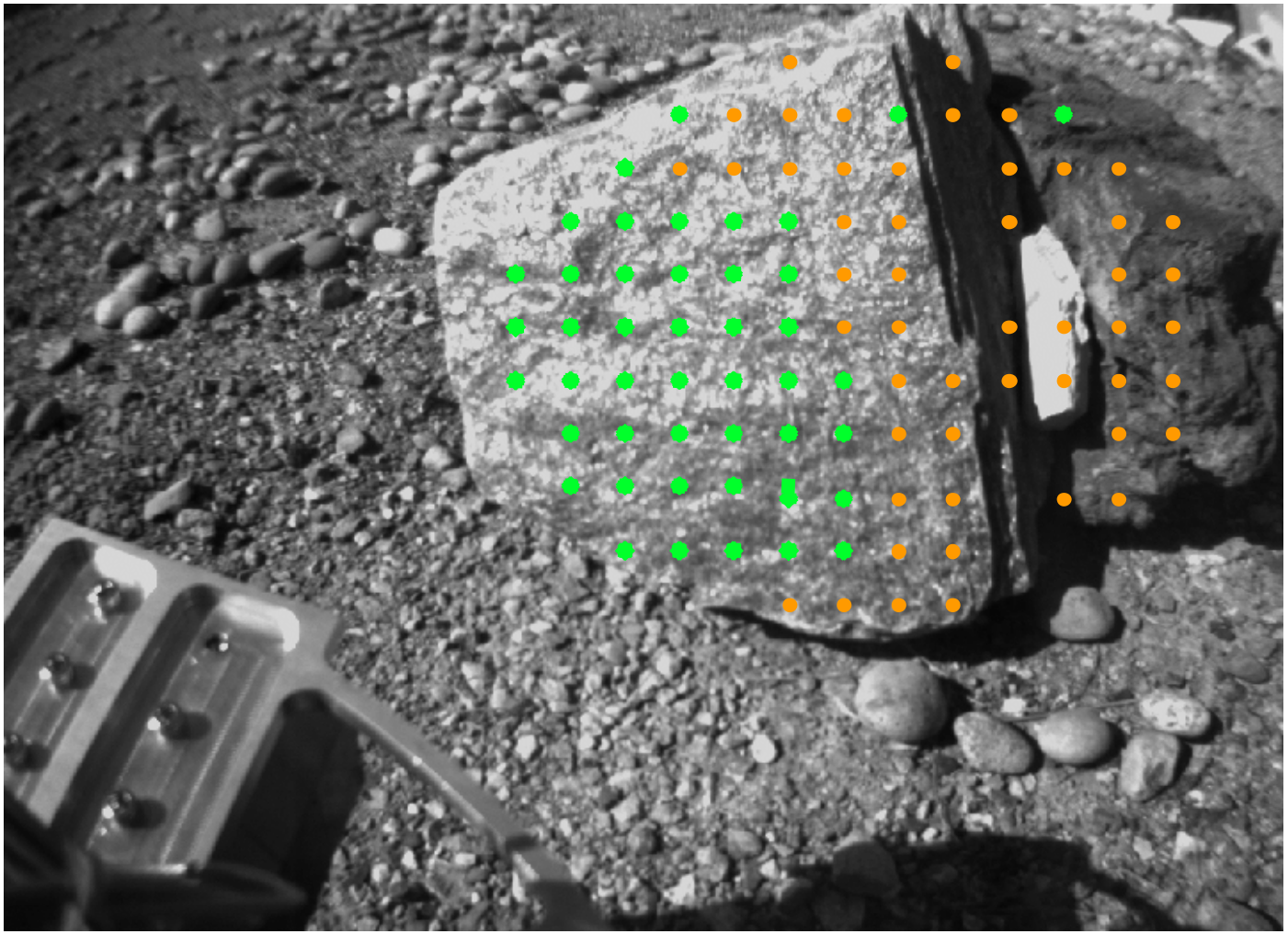
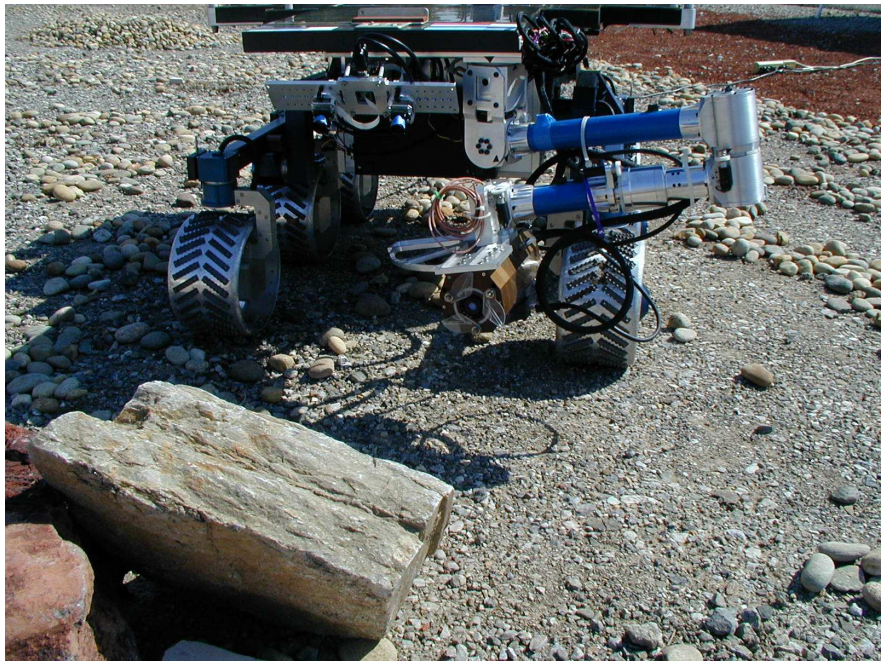
Instrument Consistency Check

(August 2002 Outdoor Demo)



Initial Arm Motion

- Direct path to initial pose point just *before* target, along surface normal, via pre-planned waypoints.
- Move arm to initial pose
  - [Track target and arm, compensate for deviations]
  - [Fault/Collision detection and diagnosis (Richard Dearden)]



August 2002 Outdoor Demo

Terminal Placement and Verification

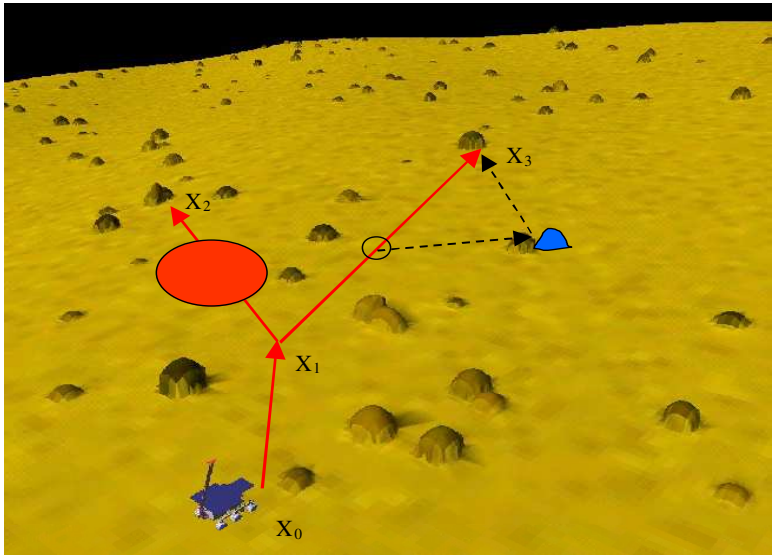
- Move final distance until force or contact sensors *verify* instrument is against target
- Orientation adjustment
  - [Active orientation correction using force control]
  - *Verify* contact and orientation
- Acquire measurement
- [Science Autonomy to verify measurement quality]
- [Recovery –
  - jiggle instrument
  - different patch
  - acquire diagnostic image and abort]

August 2002 Outdoor Demo

July 2002 Instrument Placement Demo

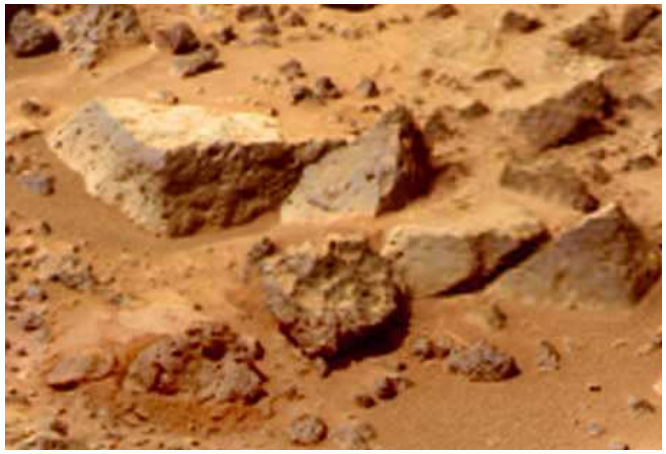
Future Plans

- Integration of
  - **Viz science interface**
  - **Ground based contingent planner**
  - **Conditional Exec**
  - Visual Servoing
  - Mission Simulation Facility
  - Fault diagnosis
- Rigorous and repeated testing
  - Ames Marscape
  - Undisclosed field location



Schedule and Goals

- FY02 Goals:
  - Flexible end-to-end system that can be incrementally improved
  - Simple environment
- FY 03
  - Integration with Exec and Ground Planner
  - Close loop on target approach
  - Progress towards *Preliminary* **Mars '09** Requirements:
  - Field tests
- FY 04
  - Field tests
  - [TRL 6 maturity]
  - [Multiple targets]



Accomplishments

Publications:

- *IROS 2002*
- ICRA 2003 *in progress*
- i-SAIRAS 2003 *in progress*

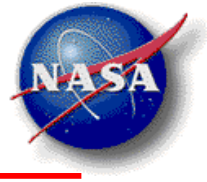
Movies

- ICRA 2003 *in progress*

Demos/Milestones:

- Autonomous instrument placement, July 2002.

Collaborations



- **Mars Technology Program**
  - K9 Infrastructure (Maria Bualat)
  - CLARAty
  - Visual Servoeing (Issa Nesnas, Maria Bualat)
- **Other IS Projects**
  - Conditional Exec (Rich Washington)
  - Contingent Planner Group (Dave Smith)
  - Mission Simulation Facility (Greg Pisanich)
- **MSL**

  Ongoing discussions
- **Others Welcome!**

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Robust Instrument Placement

PI: Liam Pedersen (QSS Group, Inc. at NASA ARC)

Problem: Mars Smart Lander science objectives require contact instrument placement in one communications cycle.

Objectives:

- **Contact instrument placement**
- **Integrate** visual servoing, obstacle avoidance, autonomous target assessment and arm control using **robust execution**.

Key Work:

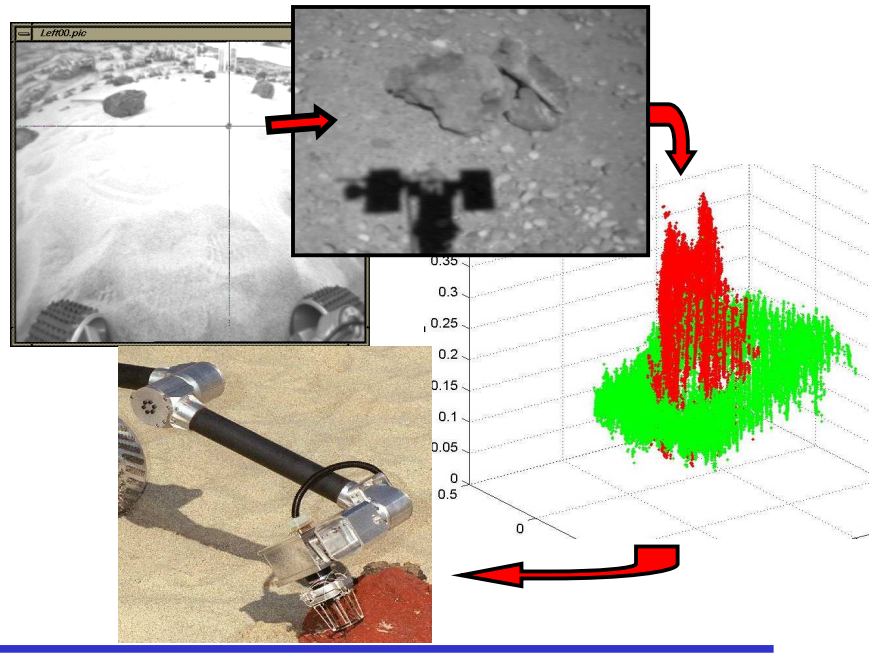
- Systematic integration of K9 rover, K9 rover arm, stereo pipeline, VIZ, and conditional exec
- Bayesian 3D target analysis

NASA Relevance:

- Enabling capability for **Mars 09 Smart Lander.**
- Supports advanced rover science autonomy

Accomplishments to date:

- 3D rock/ground segmentation (IROS)
- Autonomous instrument placement



Schedule